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U.S. ARMY HUMAN ENGINEERING LABORATORY
HELICOPTER COCKPIT LIGHTING STUDY.
PHASE I. AN EVALUATION OF CURRENT AND
POTENTIAL INSTRUMENT PANEL LIGHTING
TECHNIQUES FOR USE IN ARMY HELICOPTERS

Harry R. Stowell, et al

Human Engineering Laboratory
Aberdeen Proving Ground, Maryland

August 1974

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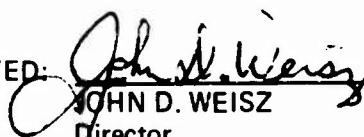
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LIGHTING TECHNIQUES FOR USE IN ARMY HELICOPTERS

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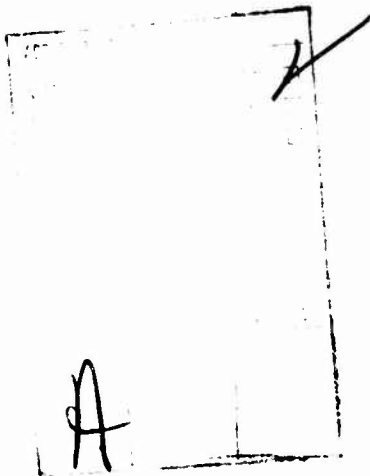
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ABSTRACT (Continue on reverse side if necessary and identify by block number) This report contains the results of the first phase of a cockpit lighting study conducted by the U. S. Army Human Engineering Laboratory. The objective of the study is to evolve lighting specifications which will alleviate current cockpit lighting problems. The objective of this phase was to quantitatively identify the problems with current lighting systems in Army helicopters. It also investigated the potential improvements afforded by some of the state-of-the-art lighting techniques. Luminance measurements were made at various points on instrument dial faces. Results are shown in tabular and pictorial forms. The results also showed that the current techniques of post and		

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eyebrow lighting are unacceptable. From a comparison of all the techniques examined, the circular edge technique gave the best light distribution. Illuminance measurements were made at the pilots' eye positions for use in other phases of the lighting study.



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CONTENTS

INTRODUCTION	3
APPARATUS	3
PROCEDURE	4
RESULTS AND DISCUSSION	5
CONCLUSIONS	5
APPENDIX	39

FIGURES

1. UH-1H Airspeed	23
2. UH-1H Altimeter	24
3. UH-1H Torque	25
4. UH-1H Dual Tach	26
5. UH-1H Contrast Ratio, High Brightness Level	27
6. UH-1H Contrast Ratio, Low Brightness Level	28
7. OH-58A Airspeed	29
8. OH-58A Altimeter	30
9. OH-58A Torque	31
10. OH-58A Dual Tach	32
11. OH-58A Contrast Ratio, High Brightness Level	33
12. OH-58A Contrast Ratio, Low Brightness Level	34
13. UH-1H Instrument Panel	35
14. OH-58A Instrument Panel	36
15. AH-1G Instrument Panel	37
16. Comparison of Light Distribution Between Dual Tachs, Red, Rated Voltage, UH-1H, OH-58A, and Circular Edge	38

TABLES

1. Illuminance Measurements (FC) UH-1H, High Brightness Level	7
2. Luminance Measurements (FL) UH-1H, High Brightness Level	8
3. Illuminance Measurements (FC) UH-1H, Low Brightness Level	11
4. Luminance Measurements (FL) UH-1H, Low Brightness Level	12
5. Illuminance Measurements (FC) OH-58A, High Brightness Level	14
6. Luminance Measurements (FL) OH-58A, High Brightness Level	16
7. Illuminance Measurements (FC) OH-58A, Low Brightness Level	18
8. Luminance Measurements (FL) OH-58A, Low Brightness Level	19
9. Illuminance Measurements (FC) AH-1G	21
10. Standard Deviation and Mean of Luminance Measurements of Individual instruments at Rated Voltage of Lamps	22

US ARMY HUMAN ENGINEERING LABORATORY HELICOPTER COCKPIT LIGHTING STUDY

PHASE I - AN EVALUATION OF CURRENT AND POTENTIAL INSTRUMENT PANEL LIGHTING TECHNIQUES FOR USE IN ARMY HELICOPTERS

INTRODUCTION

Cockpit lighting systems have presented problems to pilots since their inception. These problems have been accentuated with the importance of low-level night flying using the unaided eye to accomplish the Army's mission and the need to maintain dark adaptation for best vision performance. One of the main problems is the uneven distribution of light; not only an uneven distribution between instruments, but even within instruments. This uneven distribution causes bright spots at higher levels of illumination and dark spots at the lower levels. Both of these conditions render that part of the instrument unreadable. The pilot is forced to make a choice. He may turn all his lights up to compensate for the dark spots and destroy his dark adaptation or leave the lights dim which causes loss of legibility and increases the time to cross-check his instruments and may be the cause for reading errors.

The U. S. Army Human Engineering Laboratory (HEL) has begun a project which will be aimed at correcting some of the current problems. The first step in any project, and the goal of this phase, is to properly identify the problem. To achieve this, measurements were taken of the luminance values of the markings at various positions. Measurements were made of the instrument panels of the UH-1H and OH-58A. With each type of aircraft, measurements were taken at high as well as low brightness settings. All measurements were made at night or in a covered cockpit to keep the influence of ambient light to a minimum. Photographs were also taken at each brightness setting to help point out the problems.

The data collected would then serve as a datum base against which future experimentation with various lighting techniques can be compared.

APPARATUS

Gamma Scientific, Inc., Photometric System, consisting of the following:

- Luminance Standard Head, Model 220-1A
- Photometer, Model 2020
- Standard Lamp Source, Model 220
- Photomultiplier Detector Assembly, Model 2020-A
- Photometric Microscope, Model 700-10
- Fiber Optic Probe, Model 700-38
- Photopic Filter, 2020-1A S/N 7083
- Scotopic Filter, 2020-18 SN/ 7083
- Lamp Source Filter, 220-13

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PROCEDURE

All of the measurements were made at night and the helicopters were positioned to eliminate the effects of the light coming from the aircraft hangar, surrounding buildings, etc. Meteorological conditions at the beginning of each test session were recorded.

After calibration, the photomultiplier detector assembly was used to measure the illuminance outside the aircraft as well as inside the aircraft at the pilot's design eye position. Both readings were made with all aircraft lights off. The purpose of these measurements was to determine how much of the ambient light reaches the pilot's eye.

The instrument and console lights were adjusted to the position where they were measured. At the "high" setting, the controls were turned to full brightness which corresponded to a voltage of 28 VDC. For the "low" setting, pilots who were currently flying night missions from Phillips Army Airfield were asked to mark control positions after they were adjusted to minimum brightness level for legibility of all instrument markings. The results are as follows:

Pilot's flight instruments	18 VDC
Copilot's flight instruments	17.5 VDC
Engine instruments	21 VDC
Center console	22 VDC
Overhead console	19 VDC

Light levels in the test aircraft were then set to these levels. Photographs of the instrument panel were taken at this time.

Again, using the detector assembly, photometric measurements were made of the light density at the pilot's design eye position. The measurements consisted of a reading with instrument lights only, console lights only, and a third with both instrument and console lights. Each set of readings was taken once with a photopic filter and again with a scotopic filter. The equipment was recalibrated before each filter was used.

After recalibration, luminance measurements were made on the dial face of each instrument. Markings were measured at the 1, 4, 7 and 10 o'clock positions. Backgrounds were measured at the 12, 3, 6 and 9 o'clock positions. On those instruments whose scale is semi-circular, marking and background readings were taken at the same clock position. Pointers and legends were also measured. Certain instruments, because of their nature, could not be measured by clock positions. Therefore, on the attitude indicator, omni indicator, turn-slip indicator, and the magnetic compass, measurements were made of the key features.

For the OH-58A, measurements were made inside the aircraft hangar with the aircraft covered with a black cover. All other procedures are the same.

A second set of measurements was made in the Laboratory. HEL obtained, on loan, several instruments from Kollsman Instrument Company which employ other lighting techniques. These techniques include the standard wedge, circular wedge, and center-lit. The

instruments were available in both red and white lighting. The calibration and measurement procedures were the same as in the helicopters except all of the markings were measured.

An instrument employing a backlighting technique was fabricated from cannibalized equipment. Measurements were made similar to those for the Kollsman instruments.

RESULTS AND DISCUSSION

The results of the measurements made on the UH-1H clearly indicate the problem. The type of lighting used in this helicopter is post lighting. As can be seen from the data in Tables 1 through 4, the brightest spots are at the top of the instrument and the dimmest spots are at the bottom. Figures 1 through 4 show this data in a graphical form. Either one of these clearly shows the wide variety of luminance values within any instrument; even at the lower brightness settings.

Figures 5 and 6 show the variations of contrast ratio between instruments as well as within instruments. On the other markings, the contrast ratio was approximated by using the value of the marking and the adjacent background value (1 o'clock marking and 12 o'clock background, etc.). When computing the contrast ratios of the pointers and legends, the value used for the background was the average of the background readings at the various clock positions. These ratios are shown in the center of the instrument. When two values are given, the top value is the contrast ratio of the pointer and the bottom value is that of the legend. When only one value is shown, this represents the pointer contrast ratio. The formula used for the computation of the contrast ratio was $(L_M - L_B)/L_B$ where L_M is the luminance of the marking and L_B is the luminance of the background.

The results of the measurements made on the OH-58A are shown in Tables 5 through 8 and in graphical form in Figures 7 through 10. The contrast ratios are displayed in Figures 11 and 12. Again, as with the UH-1H, wide variations can be seen within instruments as well as between instruments.

The results of the measurements made on the instruments from Kollsman Instrument Company have not been shown in graphical form. Also, the tabular data has not been presented. Because of the large number of measurements, no comparisons can be directly applied to other systems. However, for each instrument, computations were made of the standard deviations and means and are presented in Table 10.

Photographs were taken of all of the instrument panels at each brightness level. The photographs are helpful in showing "bright spots" and areas where the dial face is so dark that it cannot be read (Figs. 13 through 15).

CONCLUSIONS

Even though some of the instruments were lit with red light while others used white light, the color of the lighting system has no effect on the objectives of this study. As the aim of this study is to determine which of the existing lighting techniques will give the best distribution of light across the dial face. The distribution of light will not change because the color of the lighting system is changed.

It is considered that the light distributions in current helicopters are unacceptable. By examining the ratio of standard deviation to mean, as shown in Table 10, it can be seen that the circular wedge technique has the lower values and hence the best distribution. It should be noted at this point, that several lighting techniques were not investigated. These include transillumination, electroluminescent, and integral other than wedge.

Of the lighting techniques tested, circular wedge lighting has the best distribution of the individual instruments. Circular wedge lighting was then compared with the lighting systems currently in use in helicopters. The circular wedge instrument was a dual tach, so a comparison was made between this and the dual tachs in the UH-1H and OH-58A. The results are shown in Figure 13. Again, it can be seen that the circular wedge technique provides the best light distribution.

Therefore, it is concluded that, on the basis of light distribution, the circular wedge technique is better than any other system that was investigated.

TABLE 1

Illuminance Measurements (FC) UH-1H, High Brightness Level

Date:	29 Nov 73	3 Dec 73
Aircraft:	70-16333	70-16333
Moon:	1/4	1/2
Voltage:	27.5 VDC	27.5 VDC
Ambient illumination:		
Outside A/C:	.0033	.0100
Inside A/C, lights off:	.0026	.0033
Internal illumination:		
Instrument lights only:		
Photopic:	.0140	.0140
Scotopic:	.0125	.0125
Instrument and control panels:		
Photopic:	.0142	.0142
Scotopic:	.0127	.0127
Control panels only:		
Photopic:	.0035	.0035

TABLE 2
Luminance Measurements (FL) UH-1H, High Brightness Level

Instrument	Clock Position									LEGEND
	1	4	Markings 7	10	12	3	Background 6	9	TIP	
Fuel Pressure	.96	.17	.096	.87	.11	.061	.033	.097	.93	1.50
Eng Oil Press	1.10	.19	.32	1.08	.068	.042	.038	.047	.31	1.20
Trans Oil Press	.46	.22	.23	.16	.073	.033	.025	.033	.23	.037
Fuel Quantity	.49	.12	.093	1.35	.067	.042	.028	.048	1.20	1.65
Dual Tach	.72	.16	.093	.19	.046	.050	.035	.033	.21	.72
Torque	.55	.13	.33	.77	.063	.080	.040	.062	.97	.58
Gas Tach	.54	.18	.29	.53	.052	.041	.039	.072	.93	.24
Exh. Gas Temp	.49	.78	.19	.14	.013	.064	.053	.042	.33	.53
Airspeed	1.20	.18	.32	.92	.070	.050	.045	.063	.88	.34
Radio Compass	1.25	.60	.70	1.40	.11	.090	.083	.097	1.60	
Altitude	.27	.46	.26	.48	.10	.050	.050	.050	.72	.95
Vertical Speed	.40	.10	.21	.21	.16	.040	.070	.060	.41	.56
Clock	.18	.19	.21	.36	.050	.050	.060	.045	.20	

TABLE 2 (con't)

Luminance Measurements (FL) UH-1H, High Brightness Level

Instrument	Clock Position						LEGEND		
	12	3	markings 6	9	12	Background 3 6			
Main Gen Load	.34	.083		1.15	.042	.023	.11	1.05	.85
Standby Gen Load	.54	.50		.64	.105	.047	.12	1.07	.77
Eng. Oil Temp	.58		.34	.88	.073	.037	.048	.90	
Trans Oil Temp	.94		.77	.82	.067	.058	.12	2.05	
DC Volts	.92	.57		.46	.078	.095	.057	.51	.89
AC Volts	1.50	.67		.43	.12	.064	.056	.39	1.65

TABLE 2 (con't)

Luminance Measurements (FL) UH-1H, High Brightness Level

Special instruments:

Turn-slip indicator

Index - .22

Pointer - .29

Ball race - .13

Ball - .035

Background - .045

Legend - .092

Attitude indicator

Sky - .49

Ground - .071

A/C symbol - 1.17

Legend - .65

Sky line - .15

Ground line - .21

Horizon - .34

Roll index - .45

Omni indicator

One o'clock position - .97

Eleven o'clock position - .82

Elevation - .78

Azimuth - .92

Index - .51

Flag - .63

Background - .095

Lower numerals - .19

Left quadrant marking - .046

Right quadrant marking - .074

Magnetic compass

Numerals - .93

Index - 8.30

Compass card - .0065

TABLE 3

Illuminance Measurements (FC) UH-1H, Low Brightness Level

Date:	6 Dec 73	10 Dec 73
Aircraft:	70-16333	70-16333
Moon:	3/4	Full
Voltage:		
Engine:	14 VDC	14 VDC
Flight:	18 VDC	18 VDC
Ambient illumination:		
Outside A/C:	.0037	.0125
Inside A/C, lights off:	.0028	.0053
Internal illumination:		
Instrument lights only:		
Photopic:		.0034
Scotopic:		.0058
Instrument and control panels:		
Photopic:		.0040
Scotopic:		.0060
Control panels only:		
Photopic:		.0040
Scotopic:		.0067

It should be noted that the moon was rising during the scotopic readings.

TABLE 4

Luminance Measurements (FL) UH-1H, Low Brightness Level

Instrument	Clock Position									LEGEND
	1	4	Markings 7	10	12	3	Background 6	9	TIP	
Fuel Pressure	.068	.059	.054	.074	.053	.043	.046	.045	.060	.111
Eng Oil Press	.092	.065	.069	.072	.049	.047	.058	.054	.065	.096
Trans Oil Press	.074	.067	.065	.063	.058	.058	.048	.047	.068	.076
Fuel Quantity	.062	.056	.055	.110	.053	.055	.050	.047	.058	.096
Dual Tach	.165	.037	.078	.115	.0145	.0044	.0036	.0041	.097	.200
Torque	.165	.0063	.093	.125	.0125	.0036	.0041	.0043	.041	.145
Gas Tach	.360	.102	.091	.185	.0130	.0110	.0075	.0078	.205	.145
Exh. Gas Temp	.112	.067	.049	.350	.0093	.0071	.0041	.0053	.089	.155
Airspeed	.215	.043	.074	.230	.0150	.0084	.0054	.0110	.205	.069
Radio Compass	.130	.048	.086	.098	.0120	.0120	.0084	.0160	.200	
Altitude	.108	.068	.063	.107	.0110	.0047	.0059	.0073	.165	.160
Vertical Speed	.165	.052	.049	.115	.0120	.0110	.0046	.0054	.140	.185
Clock	.026	.028	.030	.021	.0042	.0042	.0029	.0041	.034	

TABLE 4 (con't)
Luminance Measurements (FL) UH-1H, Low Brightness Level

Instrument	Clock Position									LEGEND
	12	3	Markings 6	9	12	Background 3 6		9	TIP	
Main Gen Load	.092	.078		.100	.077	.075		.075	.120	.115
Standby Gen Load	.088	.105		.098	.072	.098		.084	.120	.110
Eng Oil Temp	.084		.063	.073	.055		.061	.054	.078	.082
Trans Oil Temp	.112		.077	.089	.093		.063	.072	.078	.085
DC Volts	.102	.096		.092	.080	.081		.074	.097	.088
AC Volts	.130	.097		.081	.092	.079		.072	.079	.115

TABLE 4 (con't)

Luminance Measurements (FL) UH-1H, Low Brightness Level

Special instruments:

Turn-slip indicator

Index - .052

Pointer - .099

Ball race - .036

Ball - .0046

Background - .0068

Legend - .013

Attitude indicator

Sky - .064

Ground - .0072

A/C symbol - .265

Legend - .140

Sky line - .035

Ground line - .032

Horizon - .057

Roll index - .125

Omni indicator

One o'clock position - .22

Eleven o'clock position - .20

Elevation - .165

Azimuth - 190

Index - .125

Flag - .170

Background - .0094

Lower numerals - .002

Left quadrant marking - .0048

Right quadrant marking - .041

Magnetic compass

Numerals - .28

Index - .66

Compass card - .0067

TABLE 5

Illuminance Measurements (FC) OH-58A, High Brightness Level

Date:	12 Feb and 14 Feb 74
Aircraft:	70-15641
Moon:	Inside hangar with black cover
Voltage:	28.5 VDC
Ambient Illumination:	
Outside A/C:	N/A
Inside A/C, lights off:	2×10^{-5}
Internal illumination:	
Instrument lights only:	
Photopic:	.0078
Scotopic:	.00036
Instrument and console panels:	
Photopic:	.0115
Scotopic:	.00065
Control panels only:	
Photopic:	.0048
Scotopic:	.00028

TABLE 6

Luminance Measurements (FL) OH-58A, High Brightness Level

Instrument	Clock Position								LEGEND	
	1	4	7	10	12	3	6	9		TIP
Torque	.315	.175	.205	.59	.020	.029	.016	.028	.46	.69
Turb. Out. Temp.		.195	.265	.69	.0195	.043	.0143	.036	.46	.81
Gas Tach	.105	.265	.305	.255	.019	.036	.021	.029	.56	.235
Airspeed	1.09	.19	.23	.81	.029	.027	.017	.046	.63	.29
Dual Tach	.67	.18	.175	.46	.023	.017	.013	.015	.74	.64
Course Indicator	3.80	.36	.36	2.45	.24	.054	.026	.064	2.70	
Altitude	.74	.31	.34	.63	.035	.032	.018	.023	.67	.63
Vertical Speed	.29	.49	.41	.34	.037	.039	.036	.024	.89	.76
Clock	1.15	.77	1.11	.21	.052	.048	.030	.019	1.80	

TABLE 6 (con't)

Luminance Measurements (FL) OH-58A, High Brightness Level

Instrument	12	Clock Position						TIP	LEGEND
		Markings 3	6	9	12	Background 3 6			
Eng. Oil Press.	.93		.45	.47	.097	.076	.069	.34	2.35
Trans. Oil Press	.38		.41	.51	.045	.061	.056	.38	1.60
DC AMPS	.28		.26	.36	.051	.053	.044	.29	1.75
Fuel Quantity	.42		.22	.34	.047	.047	.049	.39	1.45
Special Instruments:									
Attitude Indicator									
Turn-slip Indicator									
Index - .057									
Pointer - 1.04									
Ball race - .145									
Ball - .019									
Background - .023									
Legend - .165									
Sky - .32									
Ground - .042									
A/C Symbol - .30									
Legend - .105									
Horizon - .50									
Roll Index - .059									
Roll Index pointer - .28									

TABLE 7

Illuminance Measurements (FC) OH-58A, Low Brightness Level

Date:	19 Feb 74
Aircraft:	70-15641
Moan:	Inside hangar with black cover
Voltage:	18 VDC
Ambient illumination:	
Outside A/C:	N/A
Inside A/C, lights off:	2×10^{-5}
Internal illumination:	
Instrument lights only:	
Photopic:	.00037
Scotopic:	$.42 \times 10^{-4}$
Instrument and control panels:	
Photopic:	.00056
Scotopic:	$.51 \times 10^{-4}$
Control panels only:	
Photopic:	.00018
Scotopic:	$.25 \times 10^{-4}$

TABLE 8
Luminance Measurements (FL) OH-58A, Low Brightness Level

Instrument	Clock Position									LEGEND
	Markings			Background						
	1	4	7	10	12	3	6	9	TIP	
Torque	.089	.033	.043	.093	.0125	.0092	.0074	.0087	.097	.145
Turb. Out. Temp.		.071	.058	.098	.0093	.0097	.0094	.015	.135	.098
Gas Tach	.056	.076	.072	.125	.0135	.0104	.0091	.0115	.235	.089
Airspeed	.265	.036	.041	.215	.0015	.0093	.0066	.0315	.145	.049
Dual Tach	.185	.061	.041	.145	.0004	.0097	.0073	.0006	.205	.145
Course Indicator	1.50	.106	.089	.240	.058	.0235	.0086	.0145	.78	
Altitude	.23	.077	.086	.135	.0145	.0115	.0069	.0072	.084	.112
Vertical Speed	.068	.125	.067	.102	.011	.012	.0115	.011	.091	.096
Clock	.295	.195	.255	.082	.0225	.0135	.0115	.0195	.365	

TABLE 8 (con't)

Luminance Measurements (FL) 0H-58A, Low Brightness Level

Instrument	Clock Position						TIP	LEGEND	
	12	3	6	9	12	3			
Eng. Oil Press.	.165		.116	.118	.0235	.0245	.0195	.098	.44
Trans. Oil Press.	.104		.114	.125	.0165	.0155	.0165	.097	.78
DC Amps	.079		.037	.086	.0150	.0145	.0155	.067	.365
Fuel Quantity	.092		.073	.089	.0125	.0155	.0155	.103	.335

Special Instruments:	
Attitude Indicator:	Turn-slip Indicator
Sky - .078	Index - .0165
Ground - .0105	Pointer - .295
A/C Symbol - .074	Ball race - .0285
Legend - .035	Ball - .0063
Horizon - .113	Background - .015
Roll index - .0195	Legend - .0165
Roll index pointer - .069	

TABLE 9
Illuminance Measurements (FC) AH-1G

	Scotopic	Photopic
Ambient illumination:	.00125	.00128
Internal illumination:		
High level:		
Instrument lights only:	.0093	.0157
Control panels only:	.0027	.0026
Instrument and control panels:	.0115	.0168
Dim level:		
Instrument lights only:	.00135	.00152
Control panels only:	.00035	.00041
Instrument and control panels:	.00155	.00190

TABLE 10

Standard Deviation and Mean of Luminance Measurements of
Individual Instruments at Rated Voltage of Lamps

Red lighting:			
Technique	S.D.	\bar{X}	S.D./ \bar{X}
CircularwEdge	.054	.517	.104
Wedge #1	.177	.736	.240
Wedge #2	.650	1.322	.491
Center - lit	.095	.243	.390
White lighting:			
CircularwEdge	.298	2.113	.141
Wedge #1	.584	2.293	.254
Wedge #2	.539	1.199	.449
Backlighting	.099	.158	.626

Wedge #1 and #2 refer to two different instruments illuminated by the wedge technique.

LUMINANCE - FT.L.

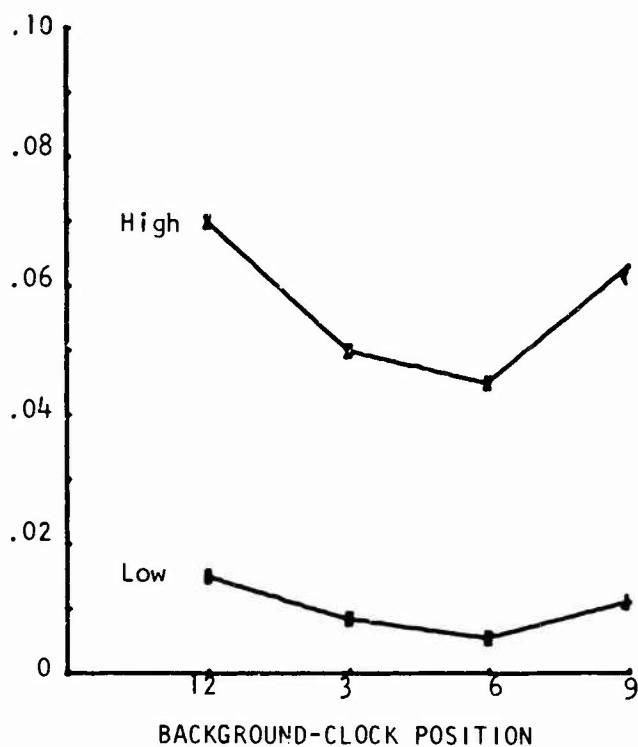
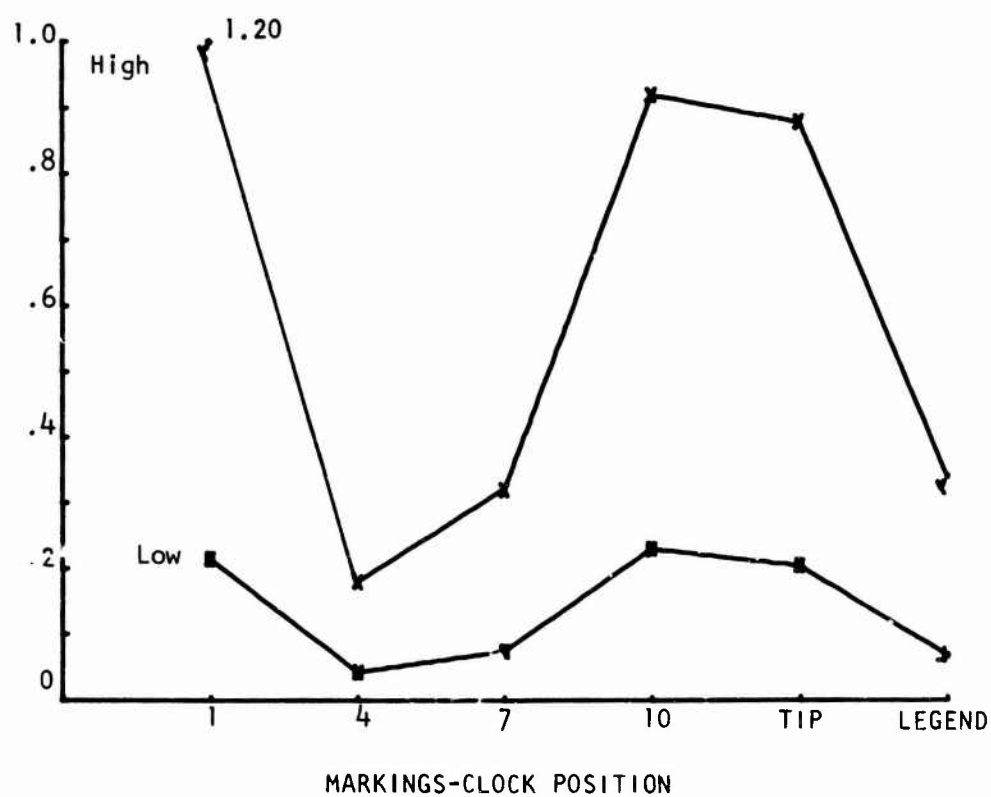


Fig. 1. UH-1H airspeed.

LUMINANCE - FT.L.

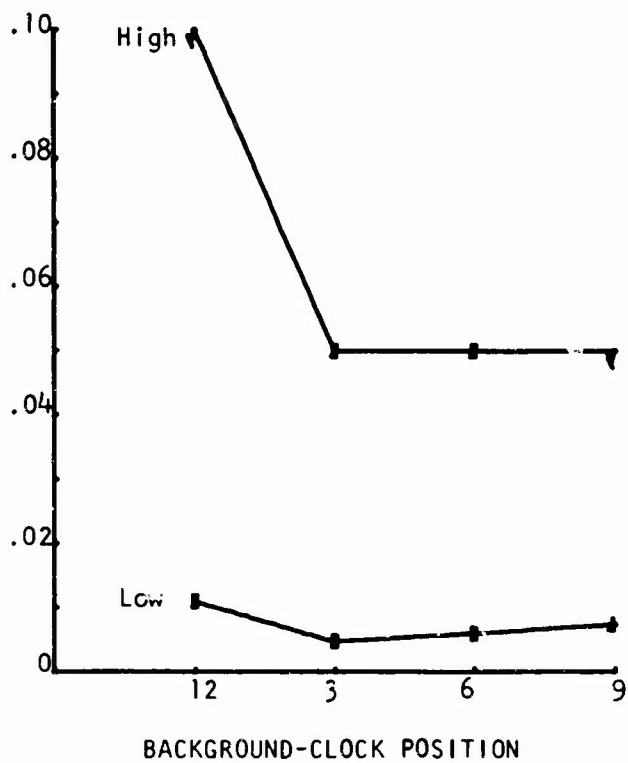
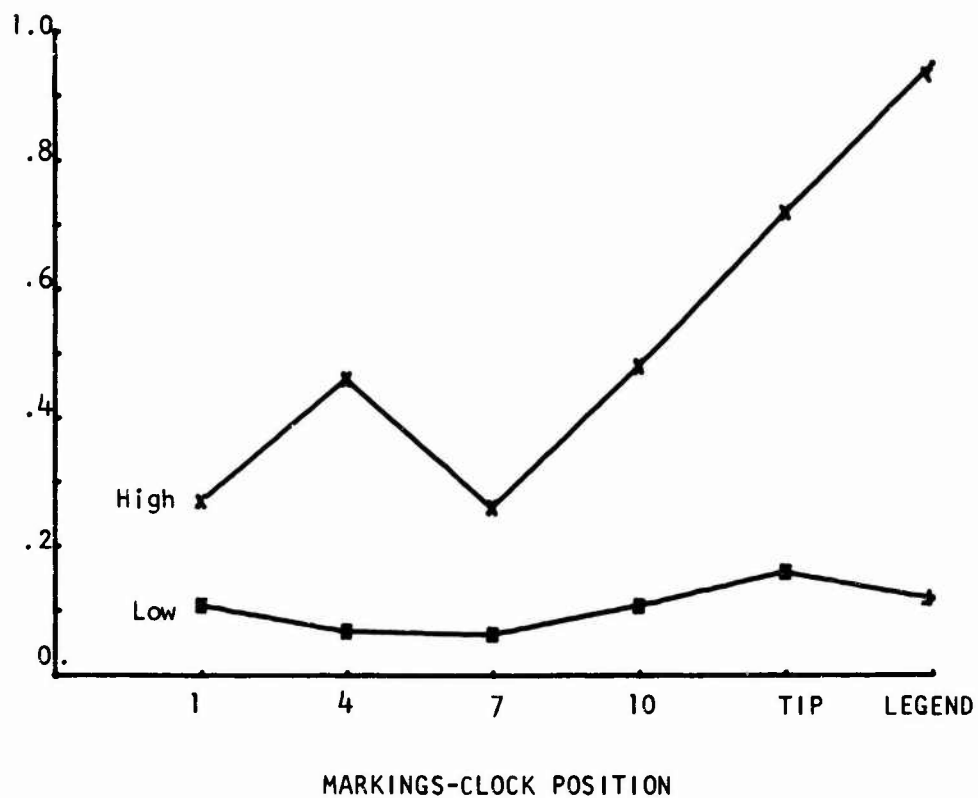


Fig. 2. UH-1H altimeter.

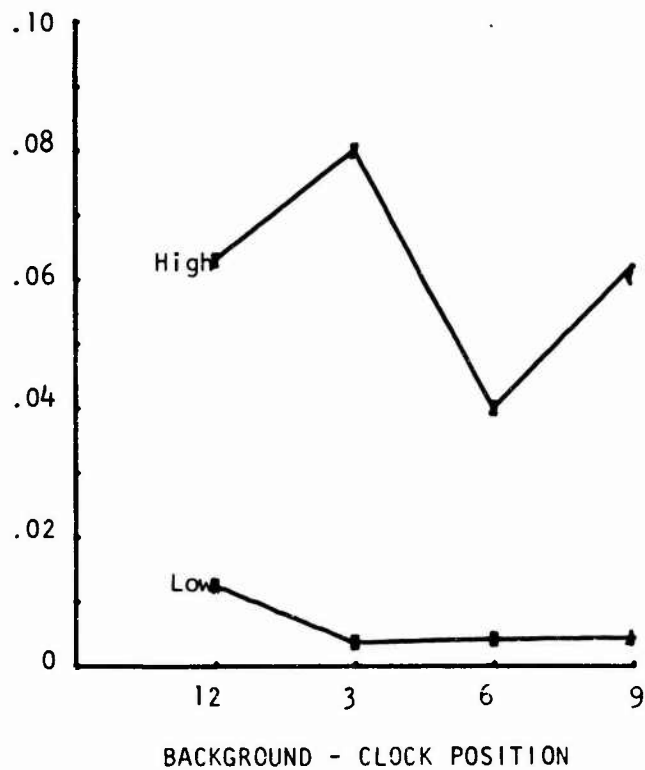
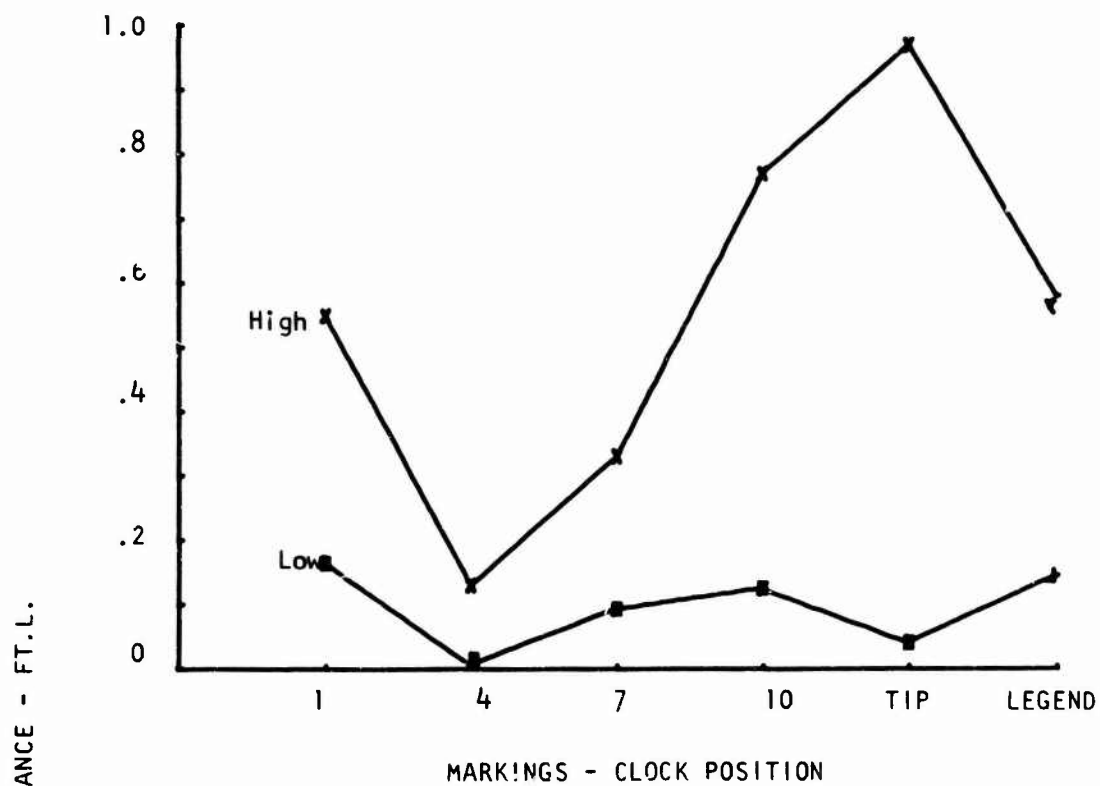


Fig. 3. UH-1H torque.

LUMINANCE - FT.L.

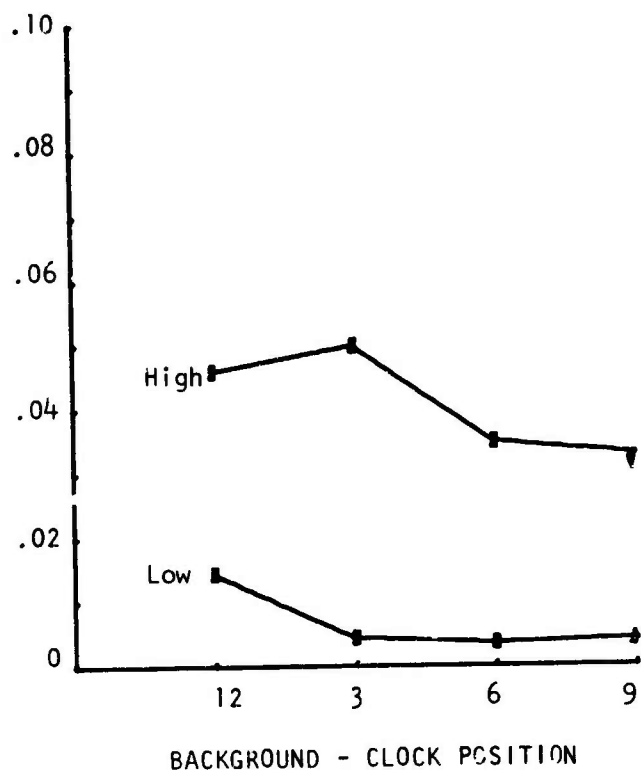
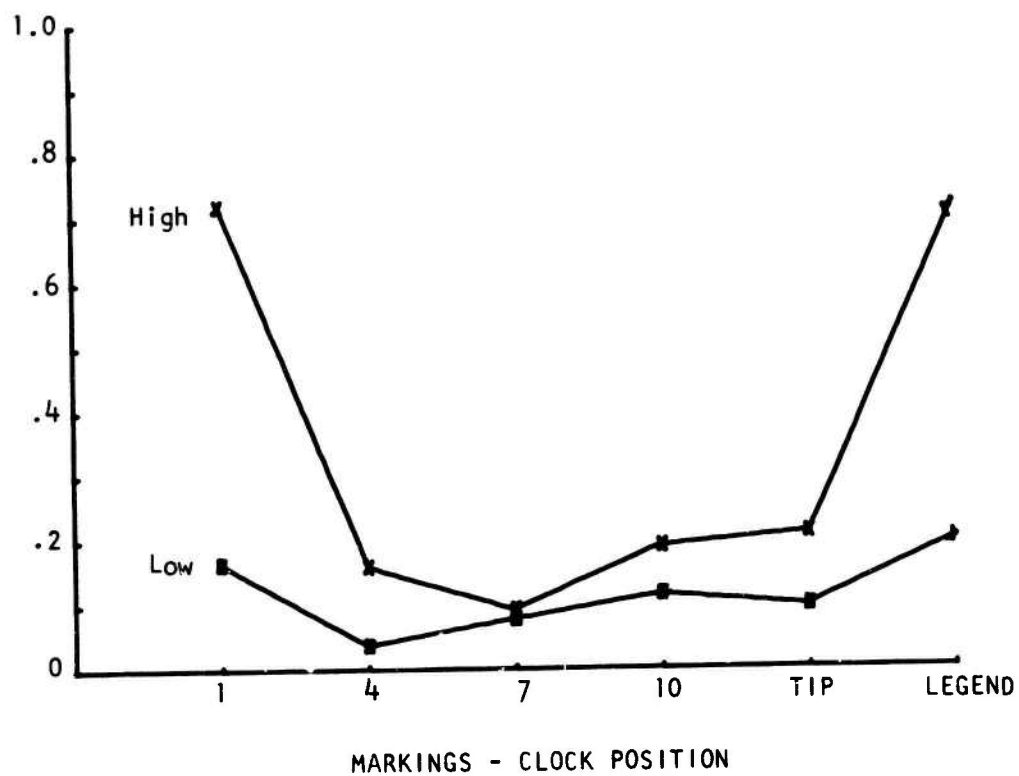


Fig. 4. UH-1H dual tach.

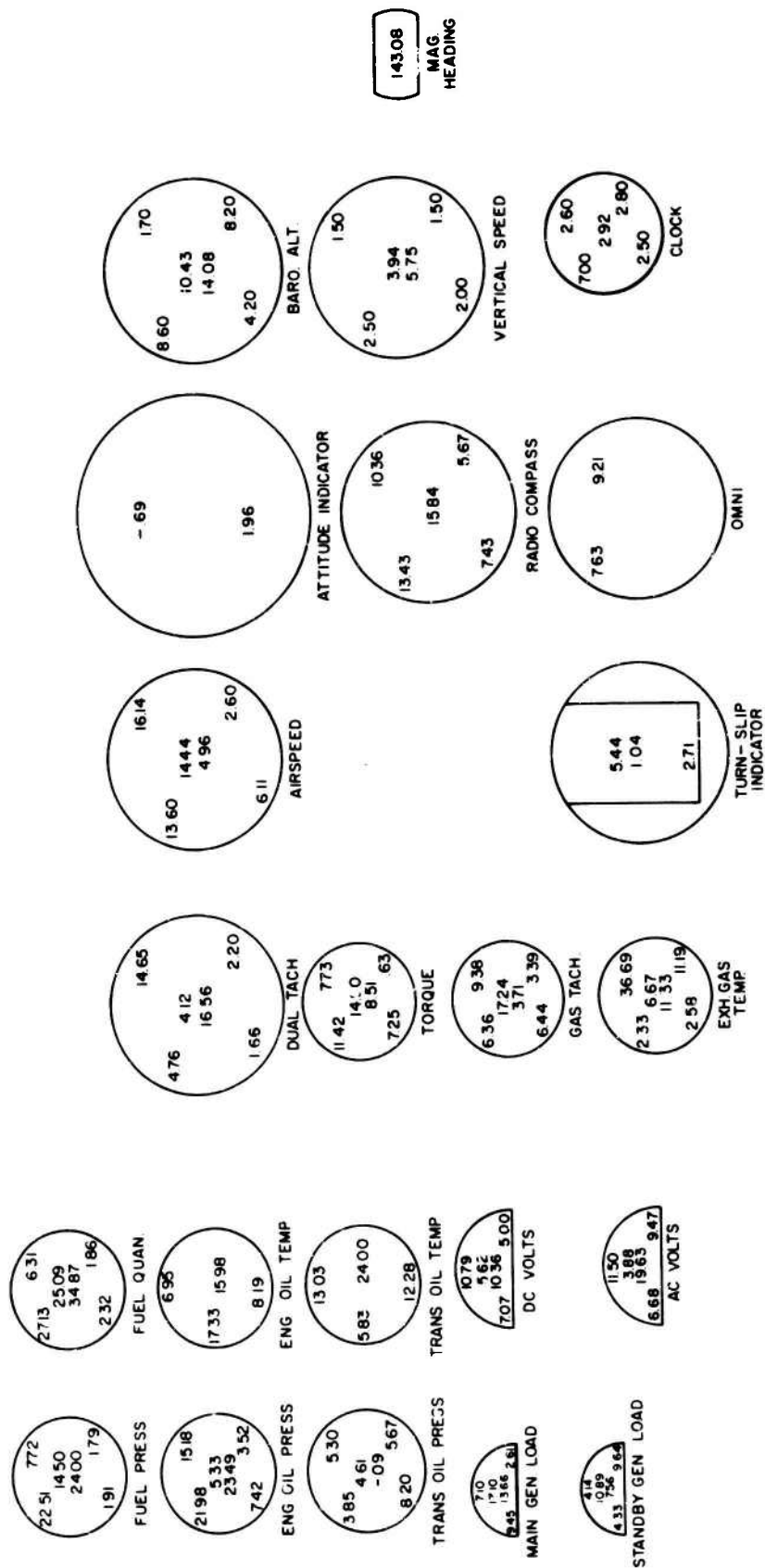


Fig. 5. UH-1H contrast ratio, high brightness level.

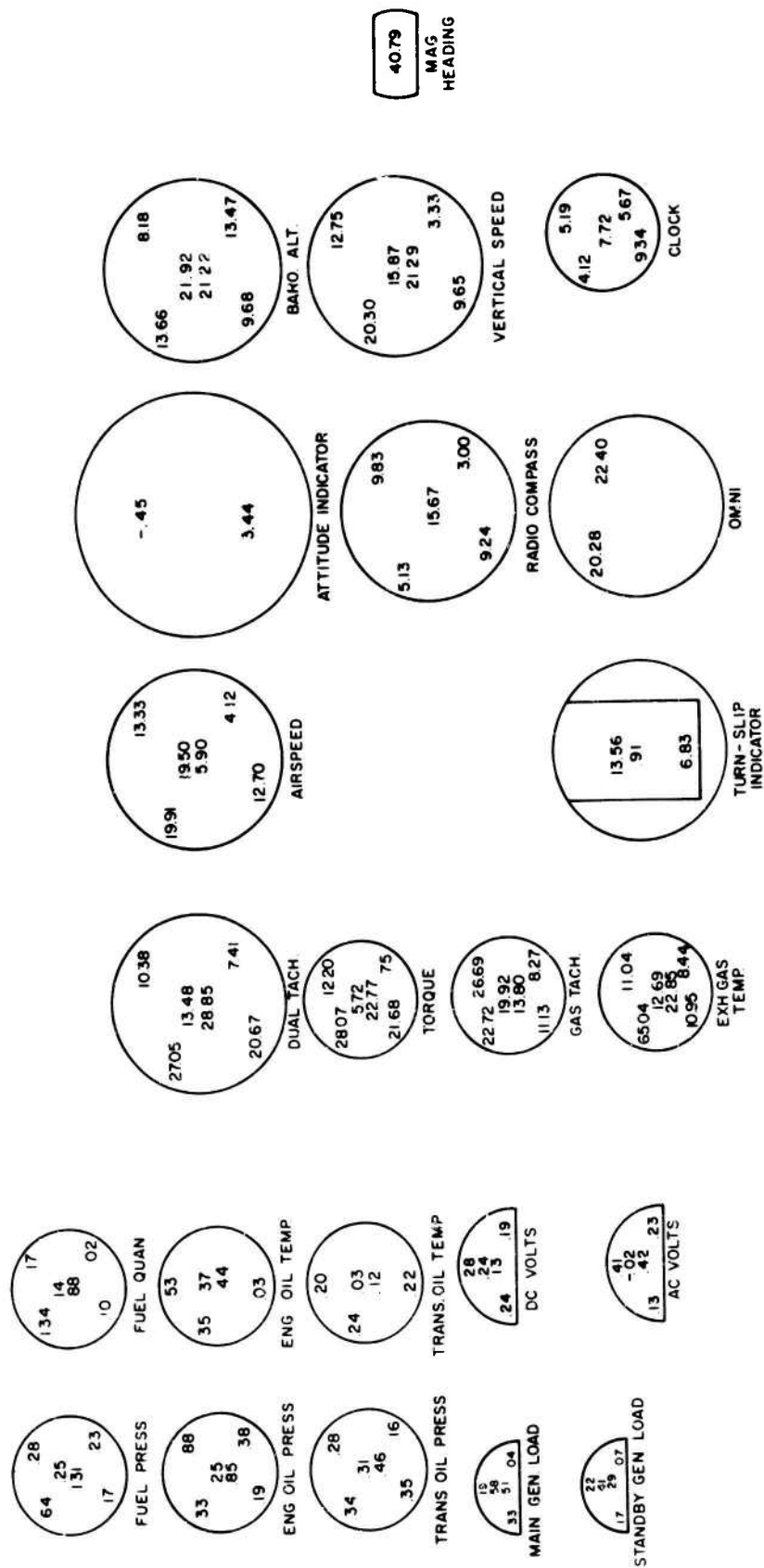


Fig. 6. UH-1H contrast ratio, low brightness level.

LUMINANCE - FT.L.

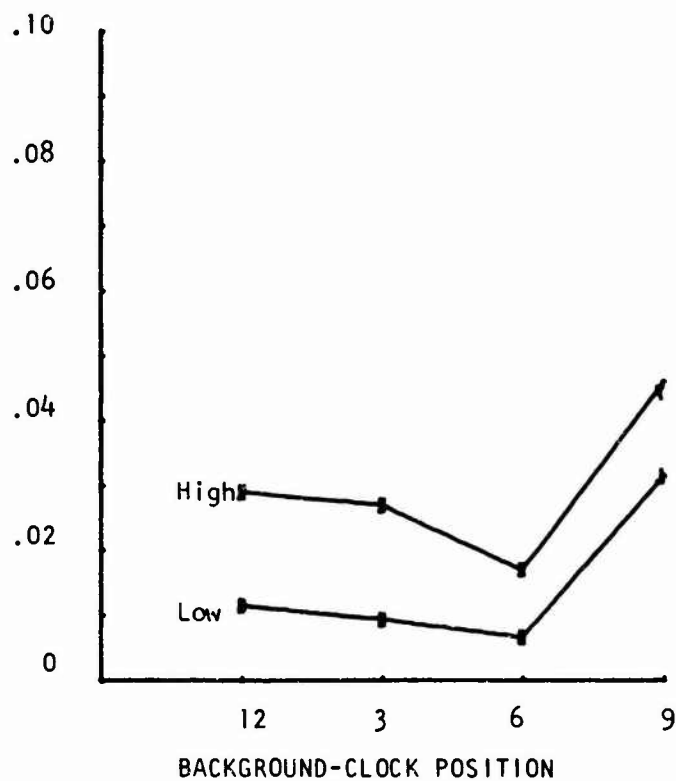
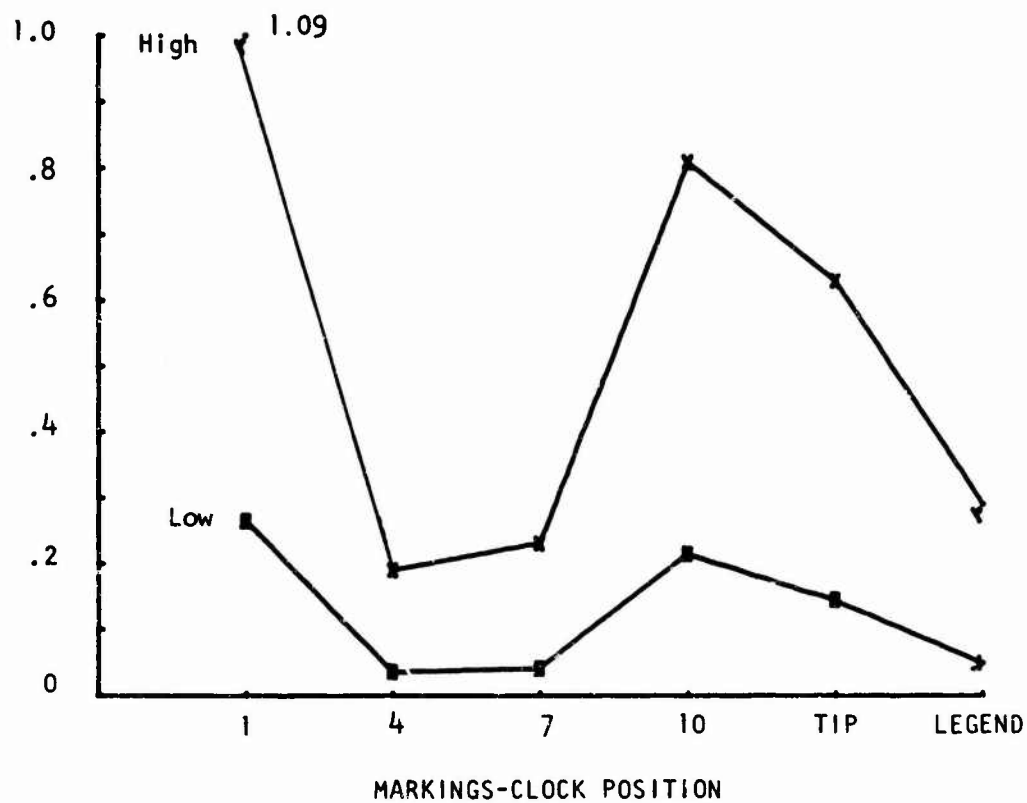


Fig. 7. OH-58A, airspeed.

LUMINANCE - FT.L.

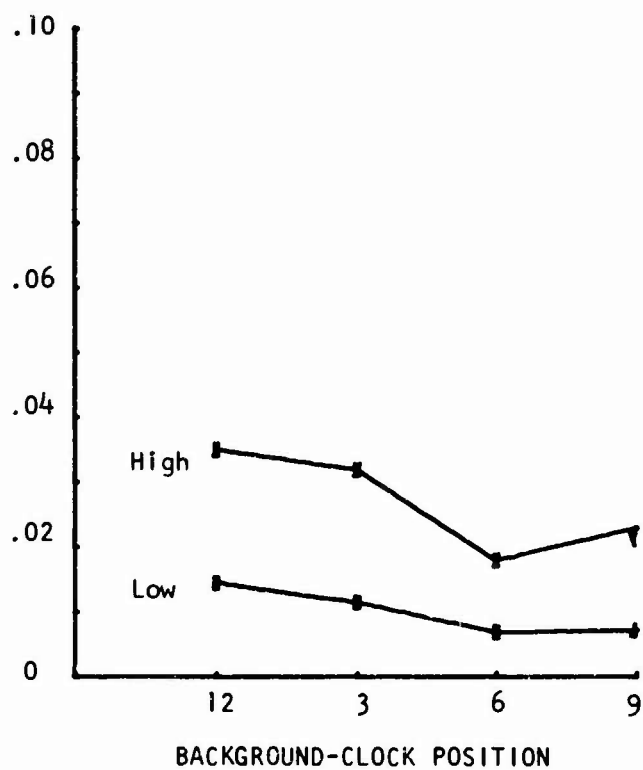
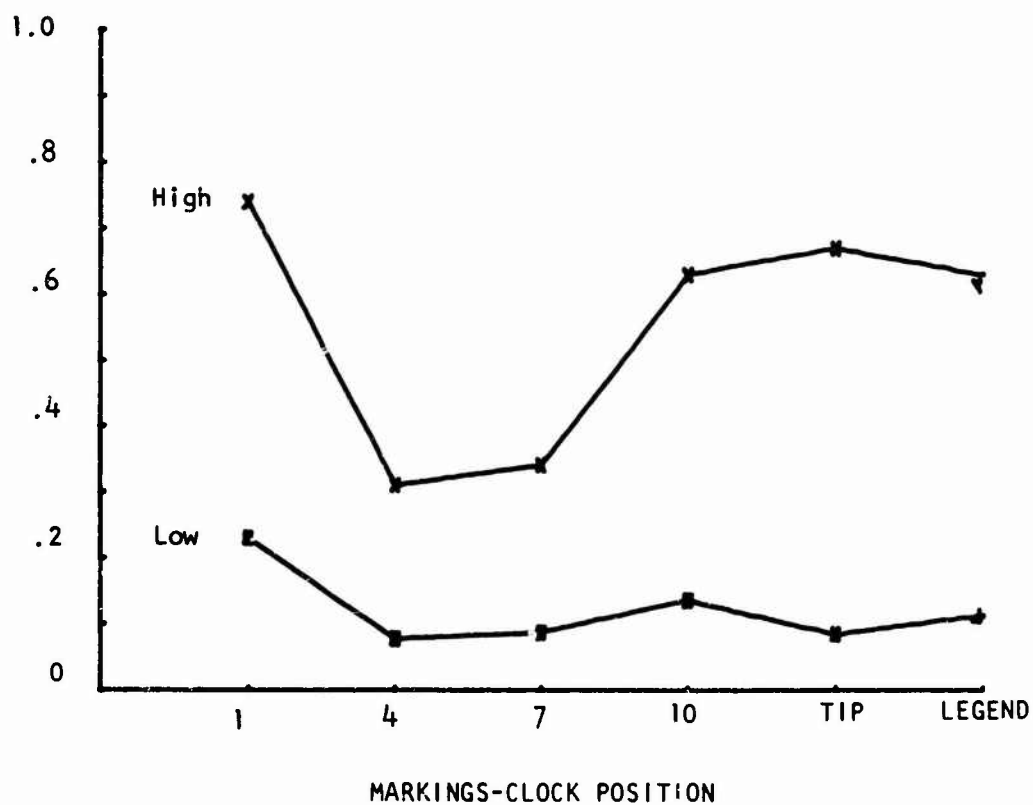


Fig. 8. OH-58A, altimeter.

LUMINANCE - FT.L.

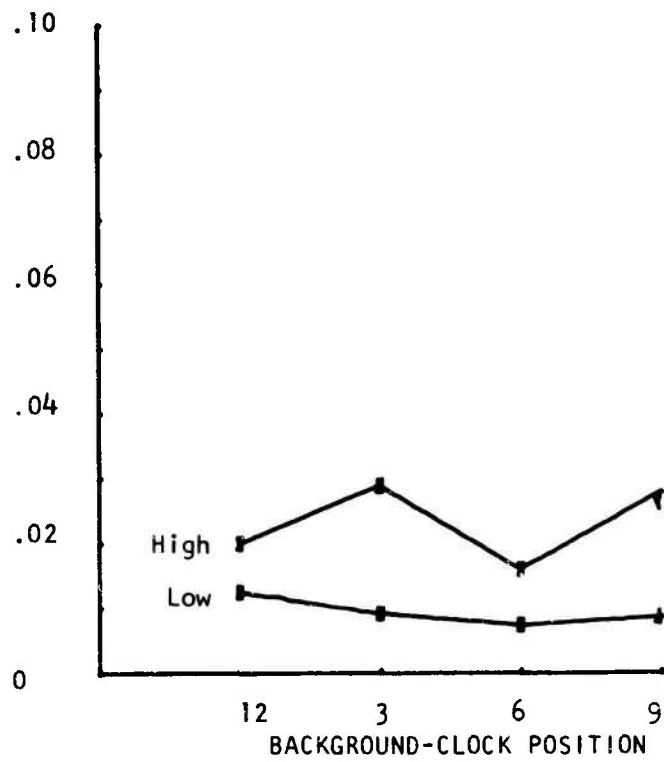
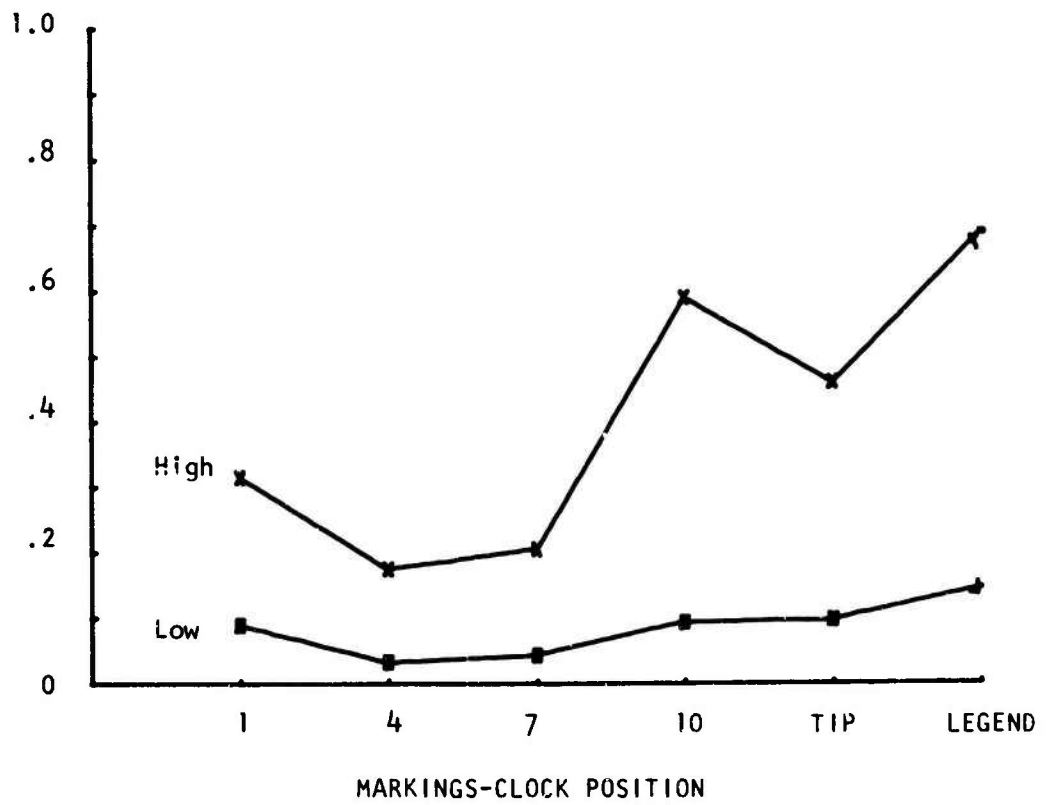


Fig. 9. OH-58A, torque.

LUMINANCE - FT.L.

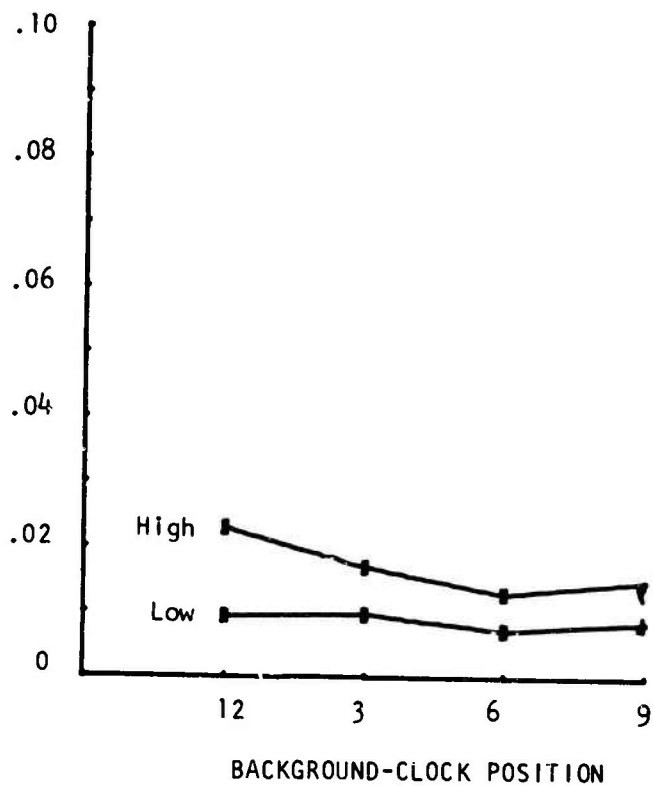
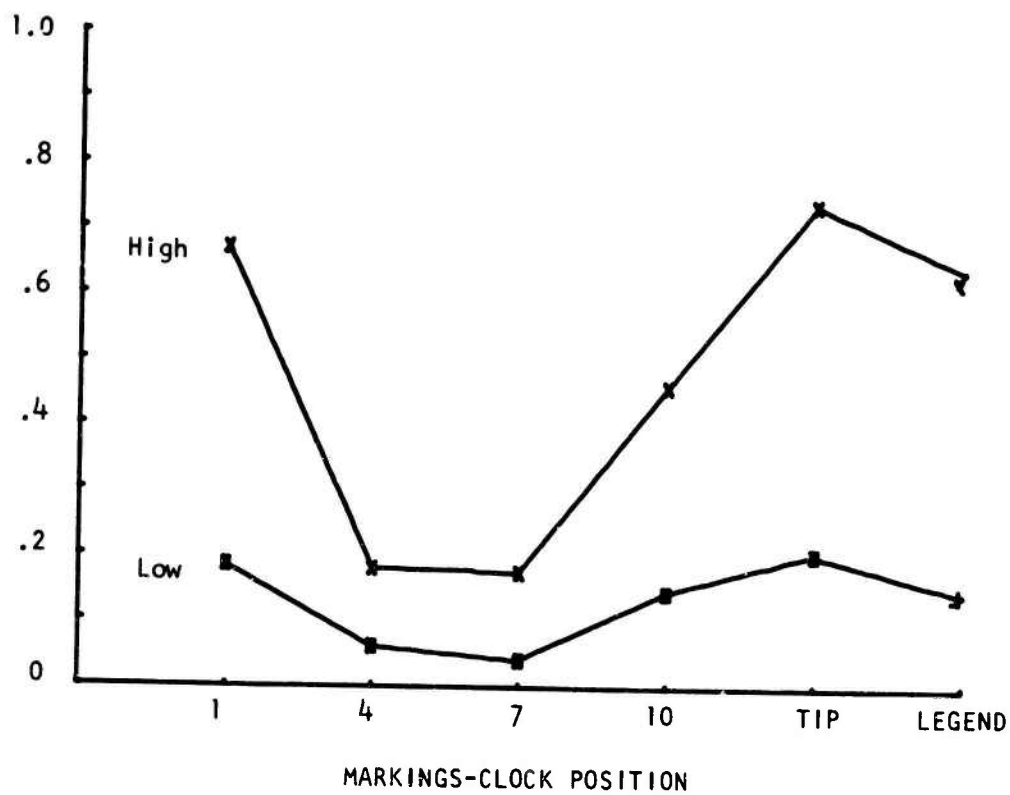


Fig. 10. OH-58A, dual tach.

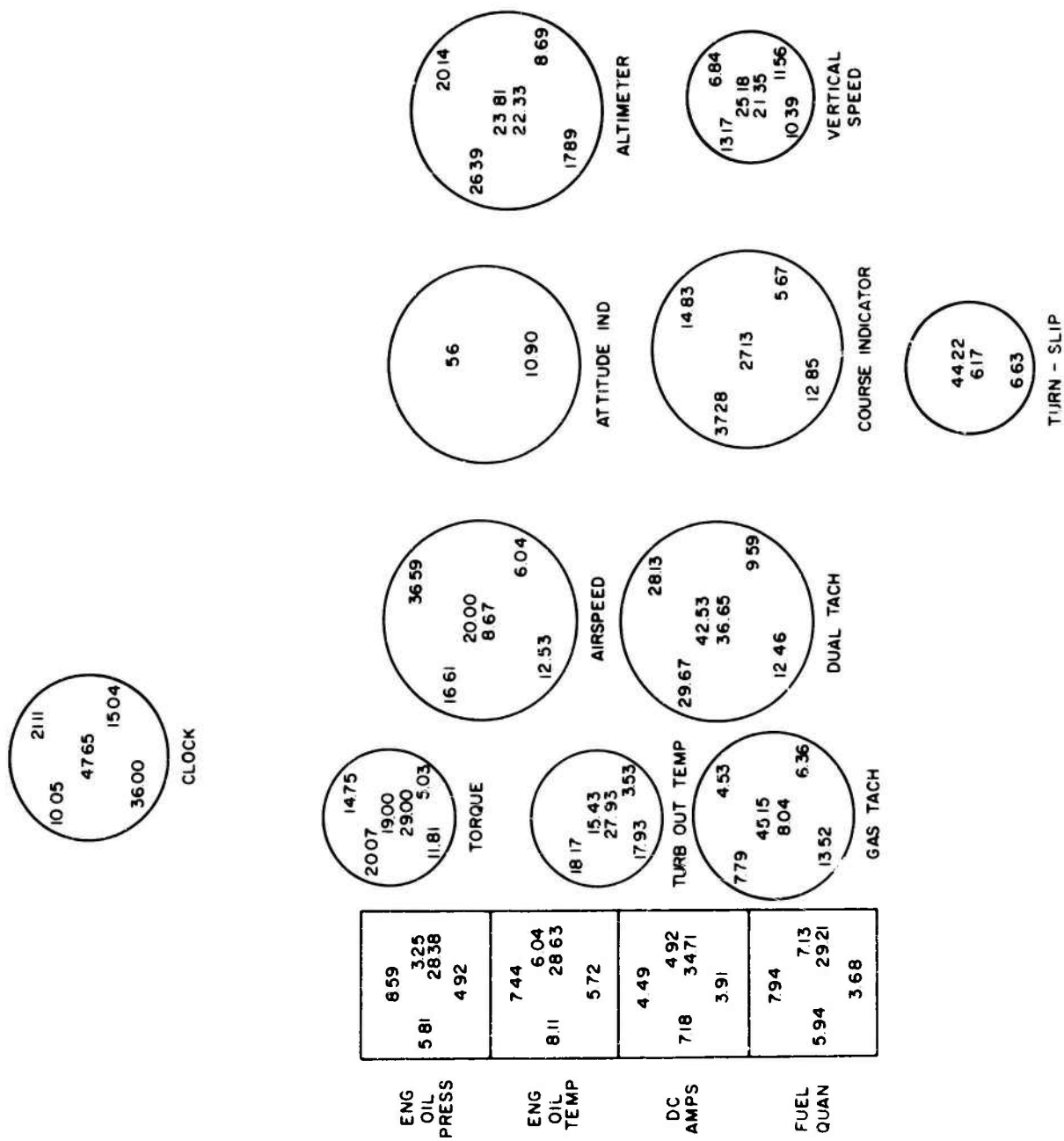


Fig. 11. OH-58A contrast ratio, high brightness level.

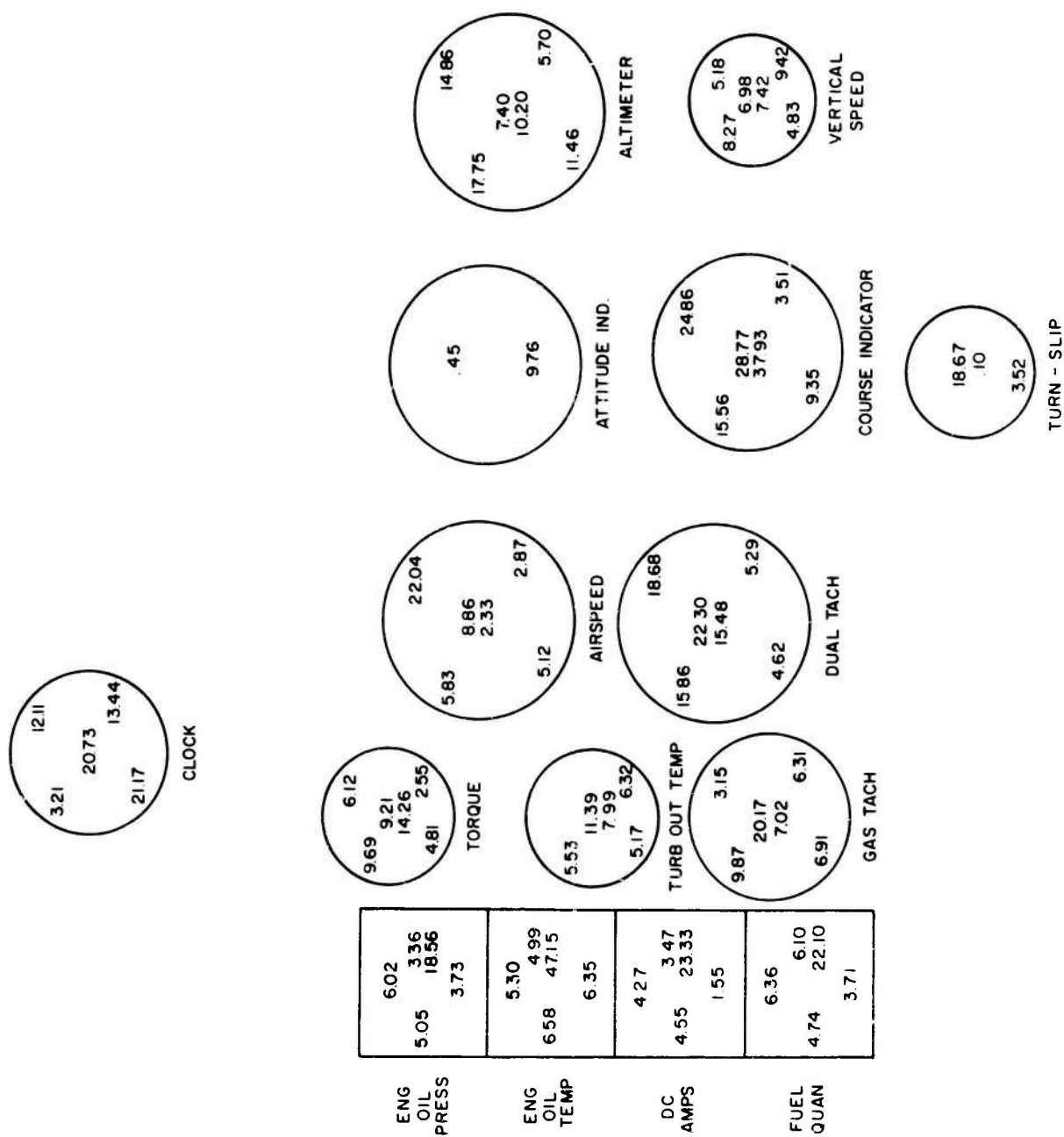


Fig. 12. OH-58A contrast ratio, low brightness level.

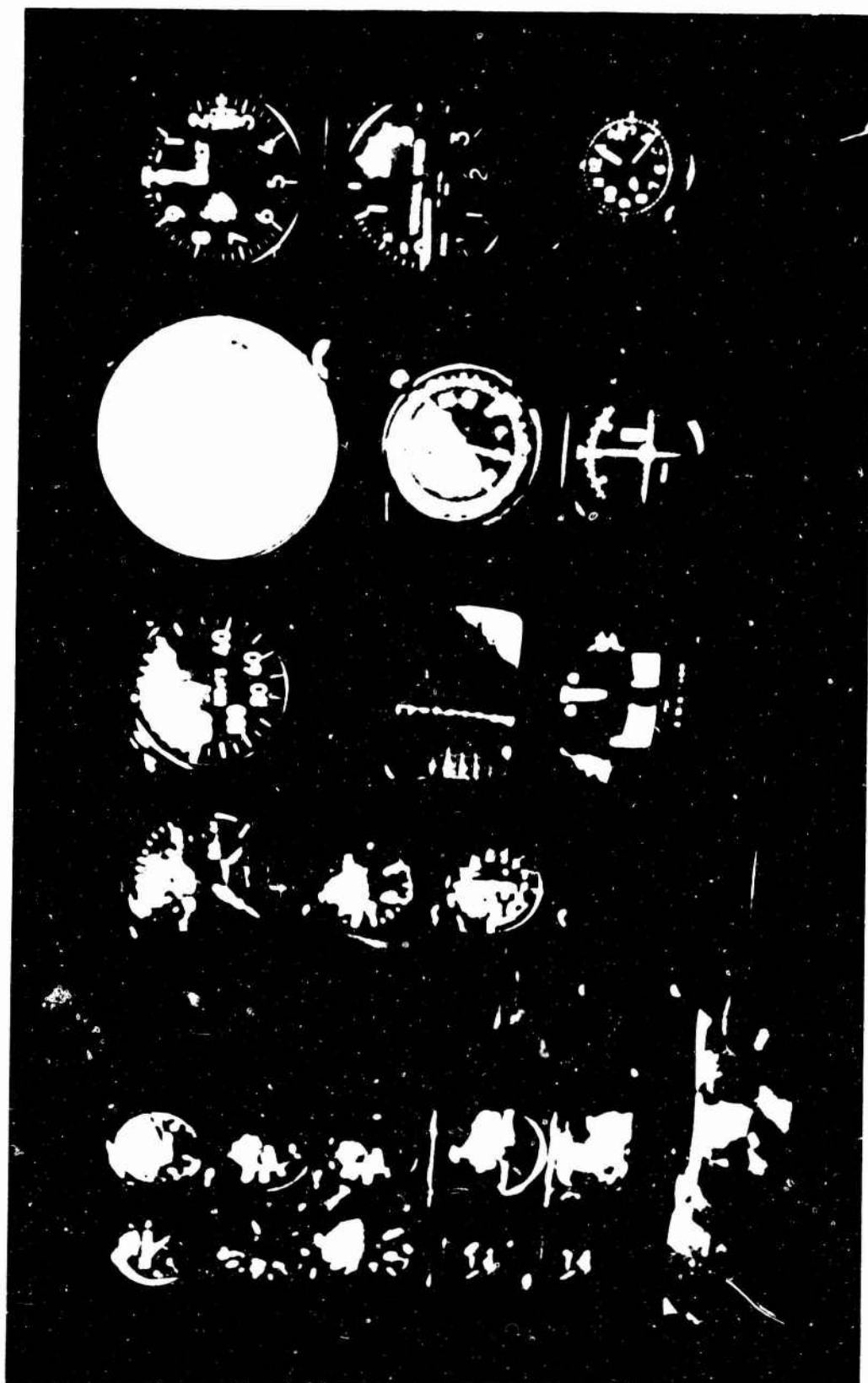


Fig. 13. UH-1H instrument panel.



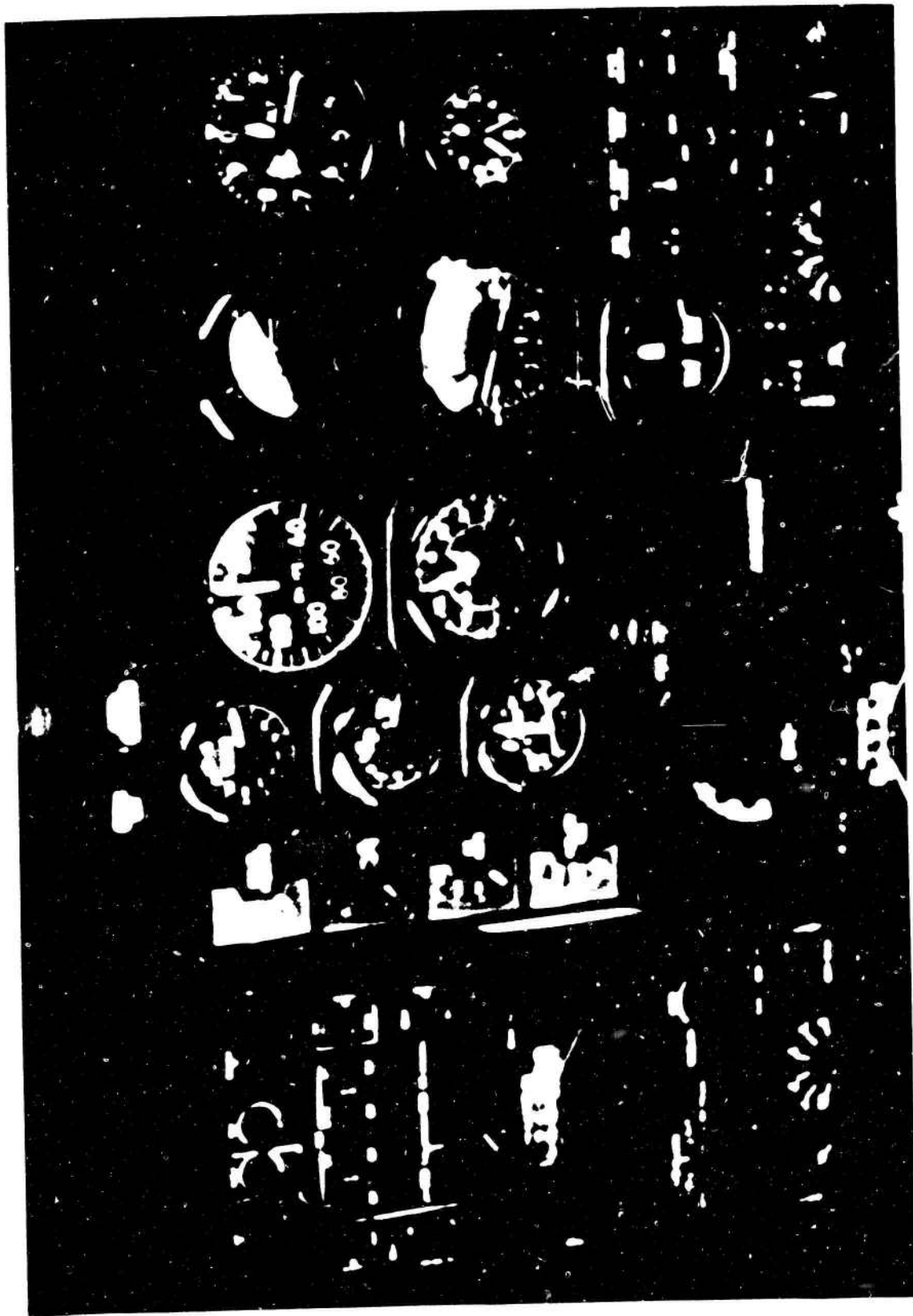


Fig. 14. OH-58A instrument panel.



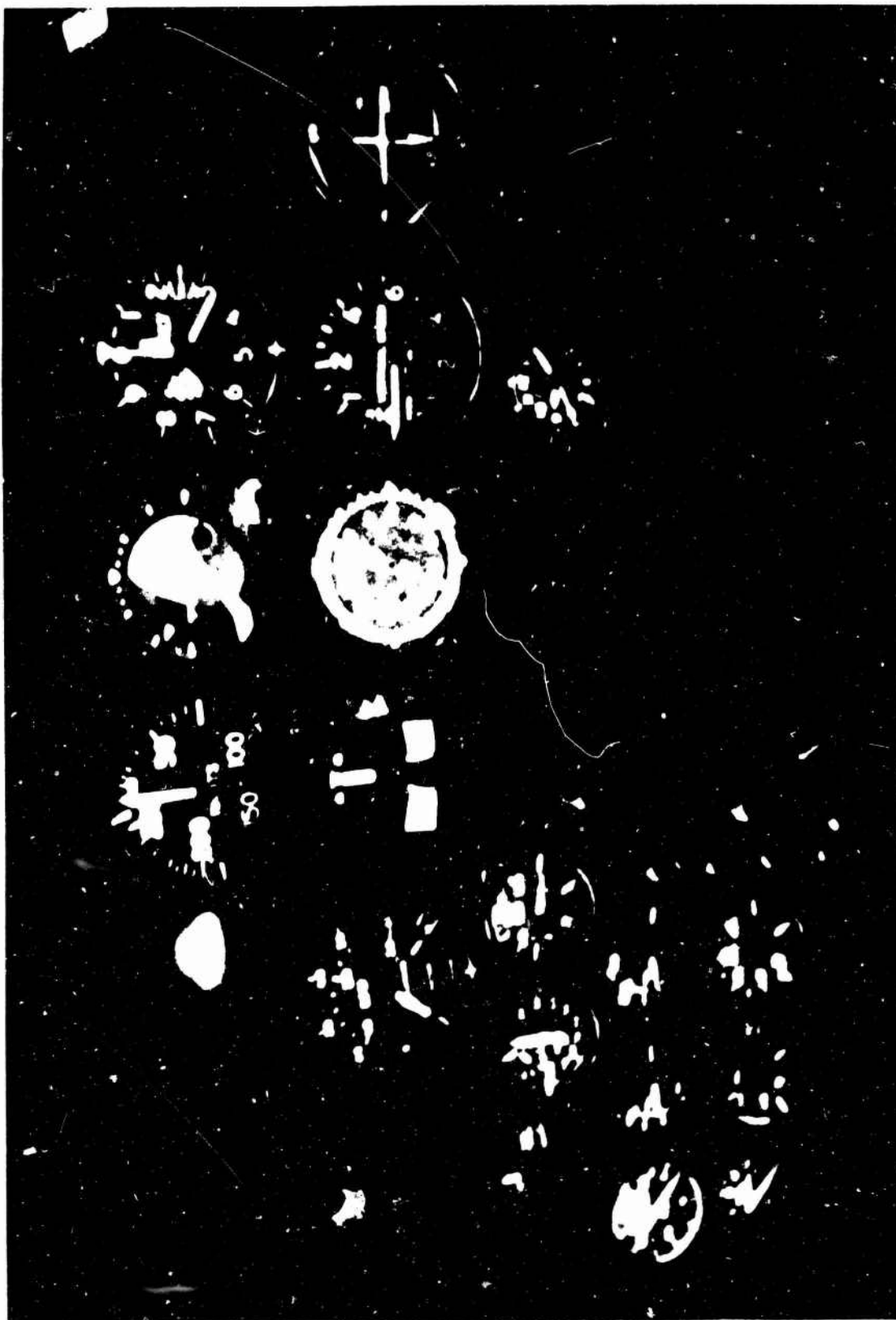


Fig. 15. AH-1G instrument panel.



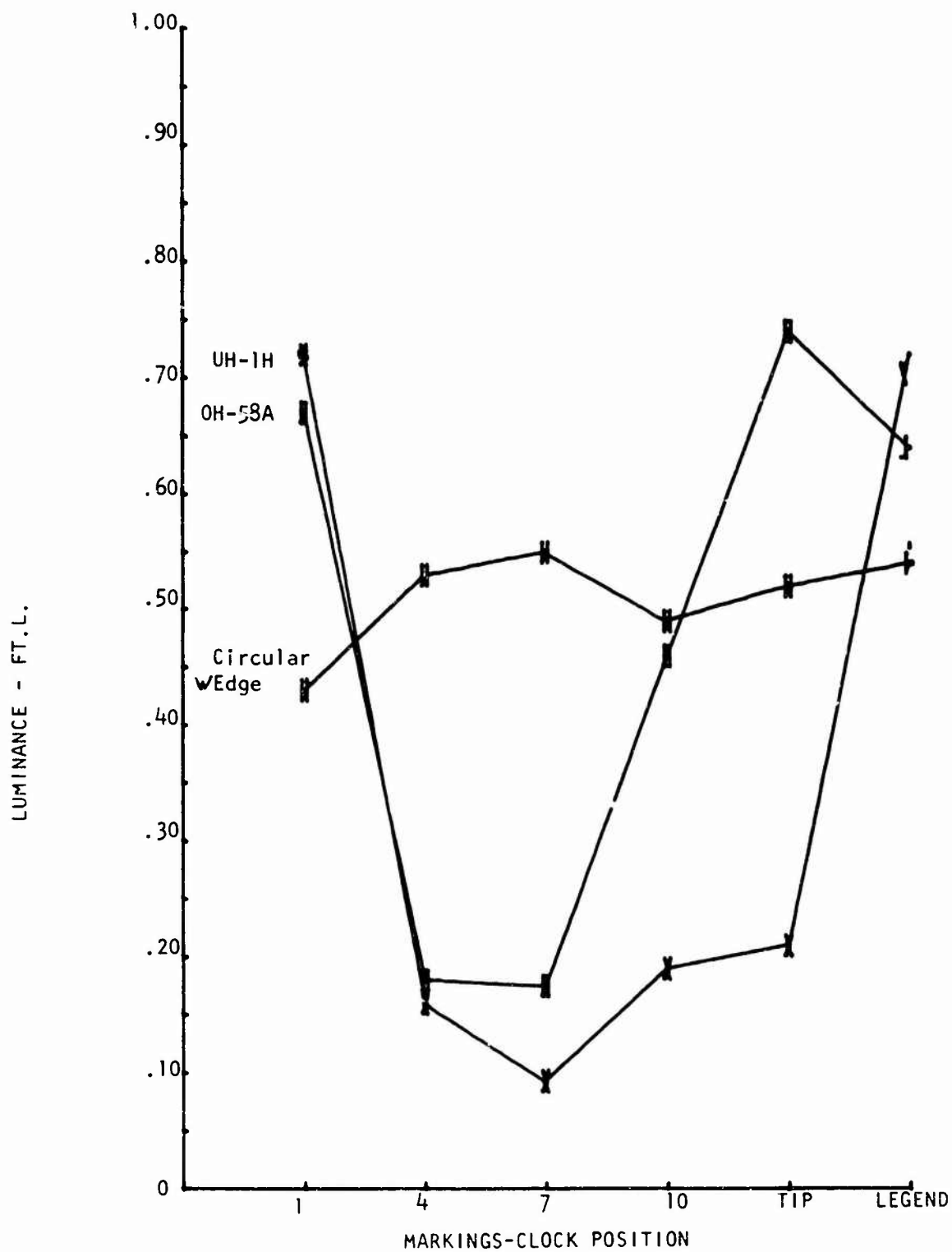


Fig. 16. Comparison of light distribution between dual tachs, red, rated voltage, UH-1H, OH-58A, and circular edge.

APPENDIX

CALIBRATION

1. Connect photomultiplier tube assembly by plugging into face of photometer.
2. Insert fiber optics probe in front of photomultiplier housing.
3. Connect other end of fiber optics probe to the microscope eyepiece.
4. Check to see that the photopic correction filter is inserted in the slit in front of the photomultiplier and that the lid is properly closed to prevent any light leaks.
5. Shut off all light to photomultiplier.
6. Turn on switch on the power supply.
7. Check the reference voltage as follows: Put the "Function" switch in the "Batt" position. The meter should read 100 ± 2 division on the main scale 0-120.
8. Turn sensitivity knob all the way counterclockwise.
9. Rotate step sensitivity control all the way counterclockwise.
10. Switch "Function" switch to "Operate."
11. Adjust "Zero" control so that meter is zeroed.
12. Switch step sensitivity control all the way clockwise, step by step, adjusting dark current to zero at each step.
13. Orient receiver to standard source and turn on standard lamp source. Open photomultiplier to light.
14. Adjust continuous variable sensitivity control for a meter deflection corresponding to the source value.
15. Shut off all light to photomultiplier and repeat Step 12, above.
16. Pull aluminum knob on top of step sensitivity control, and without changing step setting, rotate disc beneath control until appropriate full scale value is in view. Release knob to set full scale reading.

It should be noted at this point that these calibration instructions apply to the equipment from Gamma Scientific, Inc., and may vary when other equipment is used.